इंटरनेट मानक

Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

“जानने का अधिकार, जीने का अधिकार”
Mazdoor Kisan Shakti Sangathan
“The Right to Information, The Right to Live”

“पुराने को छोड नये के तरफ”
Jawaharlal Nehru
“Step Out From the Old to the New”

IS 6134-8 (1981): Methods of Measurement of Electrical Characteristics of Microwave Tubes, Part VIII: Gas-filled Microwave Switching Devices [LITD 4: Electron Tubes and Display Devices]

“ज्ञान से एक नये भारत का निर्माण”
Satyanarayan Gangaram Pitroda
“Invent a New India Using Knowledge”

Act Number 22 of 2005
The Indian Parliament
RIGHT TO INFORMATION

Made Available By
Public.Resource.Org

“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”
Bhartṛhari—Nītiśatakam
“Knowledge is such a treasure which cannot be stolen”

BLANK PAGE

BRUTUM FULMEN

IGNORANTIA JURIS NON EXCUSAT

PROTECTED BY COPYRIGHT

IS : 6134 (Part VIII) - 1981
(Reaffirmed 2003)

Indian Standard

METHODS OF MEASUREMENT OF ELECTRICAL CHARACTERISTICS OF MICROWAVE TUBES

PART VIII GAS-FILLED MICROWAVE SWITCHING DEVICES

UDC 621·387·362 : 621·317·3

© *Copyright* 1982

INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Price Rs 12·00 *March* 1982

Indian Standard

METHODS OF MEASUREMENT OF ELECTRICAL CHARACTERISTICS OF MICROWAVE TUBES

PART VIII GAS-FILLED MICROWAVE SWITCHING DEVICES

Electron Tubes Sectional Committee, LTDC 9

Chairman	*Representing*
Shri H. R. Bapu Seetharam	Bharat Electronics Ltd, Bangalore
Members	
Shri B. S. Venugopalan (*Alternate* to Shri H. R. Bapu Seetharam)	
Dr S. S. S. Agarwala	Central Electronics Engineering Research Institute (CSIR), Pilani
Dr G. S. Sidhu (*Alternate*)	
Shri B. P. Ghosh	National Test House, Calcutta
Shri B. C. Mukherjee (*Alternate*)	
Shri P. K. Jain	Ministry of Defence (R & D)
Dr J. N. Maiti	West Bengal Electronics Industrial Development Corporation Ltd, Calcutta
Dr P. B. Parikh	The Radio Electronics and Television Manufacturers' Association (RETMA), Bombay
Representative	Bhabha Atomic Research Centre, Bombay
Research Engineer	Directorate General of All India Radio, New Delhi
Shri P. S. Saran	Posts and Telegraphs Department, New Delhi
Shri G. K. Saran (*Alternate*)	
Shri Sarwan Kumar	Directorate General of Civil Aviation, New Delhi
Shri V. S. Mitra (*Alternate*)	
Col R. K. Sud	Ministry of Defence (DGI)
Shri G. N. Sahai (*Alternate*)	
Shri K. K. Taneja	Directorate General of Technical Developments, New Delhi
Shri R. Soundhirarajan (*Alternate*)	

(*Continued on page* 2)

© *Copyright* 1982

INDIAN STANDARDS INSTITUTION

This publication is protected under the *Indian Copyright Act* (XIV of 1957) and reproduction in whole or in part by any means except with written permission of the publisher shall be deemed to be an infringement of copyright under the said Act.

(*Continued from page* 1)

Members	*Representing*
Dr R. C. Tripathi	Department of Electronics, New Delhi
Shri Tek Chandani (*Alternate*)	
Shri R. C. Jain, Head (Electronics)	Director General, ISI (*Ex-officio Member*)

Secretary

Shri Pavan Kumar
Assistant Director (Electronics), ISI

Panel for Microwave Tubes, LTDC 9 : P5

Convener	
Dr G. S. Sidhu	Central Electronics Engineering Research Institute (CSIR), Pilani
Members	
Dr J. L. Bahri (*Alternate* to Dr G. S. Sidhu)	
Shri A. K. Ghosh	Indian Telephone Industries Ltd, Bangalore
Shri M. A. Narasimhan (*Alternate*)	
Shri B. L. Gupta	Bhabha Atomic Research Centre, Bombay
Shri M. S. Krishnan	Directorate-General of Civil Aviation, New Delhi
Wg Cdr Lakhmi Singh	Ministry of Defence (R & D)
Shri M. H. V. Murthy	Ministry of Defence (R & D)
Wg Cdr K. V. Padmanabhan (*Alternate*)	
Representative	Tata Institute of Fundamental Research, Bombay
Shri P. S. Saran	Posts and Telegraphs Department, New Delhi
Shri A. K. Subramanian	Ministry of Defence (R & D)
Shri K. U. Limaya (*Alternate*)	
Lt Col R. K. Sud	Ministry of Defence (DGI)
Maj S. K. Kapoor (*Alternate*)	
Shri B. S. Venugopalan	Bharat Electronics Ltd, Bangalore
Dr D. S. Venkateshwarlu (*Alternate*)	

Indian Standard

METHODS OF MEASUREMENT OF ELECTRICAL CHARACTERISTICS OF MICROWAVE TUBES

PART VIII GAS-FILLED MICROWAVE SWITCHING DEVICES

0. FOREWORD

0.1 This Indian Standard (Part VIII) was adopted by the Indian Standards Institution on 23 June 1981, after the draft finalized by the Electron Tubes Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 This standard covers the methods of measurement of electrical characteristics of gas filled microwave switches devices.

0.3 Methods of measurement of different types of microwave tubes are being covered in a series of standards consisting of the following individual parts.

Part I	Common to all microwave tubes
Part II	Oscillator tubes
Part III	Amplifier tubes
Part IV	Magnetrons
Part V	Parasitic noise
Part VI	Low power oscillator klystrons
Part VII	High power klystrons
Part VIII	Gas-filled microwave switching devices
Part IX	Backward-wave oscillator tube — 'O' type
Part X	Crossed-field amplifier tubes

0.4 While preparing this standard assistance has been derived from IEC Pub 235-7 (1972) ' Measurement of the electrical properties of microwave tubes: Part 7 Gas filled microwave switching devices' issued by International Electrotechnical Commission.

0.5 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

---

*Rules for rounding off numerical values (*revised*).

1. SCOPE

1.1 This standard (Part VIII) specifies the methods of measurement of electrical characteristics of gas-filled microwave switching devices.

2. TERMINOLOGY

2.1 For the purpose of this standard the terms and definitions given in IS : 1885 (Part IV/Sec 3)-1970* shall apply.

3. GENERAL REQUIREMENTS

3.1 Reference Point and Voltages — The polarity of all voltages applied to the electrodes is stated relative to the body of the tube.

3.2 Measuring Equipment

3.2.1 *Test Mount* — The use of prescribed test cavities or test mounts is implicit for the measurements described in **4** and the term ' tube ' is assumed to include the mount or cavity.

3.2.2 *Directional Couplers* — Where a directional coupler is used to measure incident power, care should be taken to select one of adequate directivity.

3.3 DC Primer (Ignitor) Supply

3.3.1 Because many of the tube parameters are affected by the dc primer (ignitor) supply voltage or current, this voltage or current should be within ± 2 percent of the stated value. When the value of dc voltage is stated as a primer (ignitor) supply condition, the total resistance of the supply source should be within ± 5 percent of the stated value, and the regulation of the voltage source over the current range from zero to the operating current should be better than 1 percent.

3.3.2 The superimposed ripple component of the supply voltage should be not greater than 1 percent peak-to-peak.

3.3.3 Not less than 0·5 MΩ of the total resistance of the supply source should be connected directly to the primer (ignitor) electrode of the tube under test. Primer (ignitor) resistors that are built into the tube are considered as part of this source resistance.

3.4 Holding Period

3.4.1 In order to avoid errors of measurement, tubes are stored in darkness and free from ionizing radiations for at least a stated period before any measurement of primer (ignitor) ignition period is performed, unless otherwise stated.

---

*Electrotechnical Vocabulary: Part IV Electron tubes, Section 3 Microwave tubes.

3.5 High-Power RF Load Characteristics

3.5.1 Wherever practicable, the high-power RF load should have a vswr not exceeding 1·1 : 1 at the reference frequency and a sufficiently wide bandwidth to ensure that moding of the supply oscillator will not influence the measurement.

3.6 Firing Measurement

3.6.1 The measurement described in **4.3.1** should be performed before any other high-level measurement.

3.7 Resonance Tuning

3.7.1 Tuning to the resonance frequency of a tube is indicated where possible by the minimum (TR) or maximum (ATR) value of vswr. When the vswr method is not convenient, resonance is obtained by tuning for a pronounced peak (TR) or minimum (ATR) in the observed transmitted power.

3.8 Reference-Frequency Tolerances

3.8.1 For general measurements, the allowable tolerances for the reference frequency are as follows:

a) ± 1 percent for high-power measurements; and
b) ± 0·1 percent for low-power measurements.

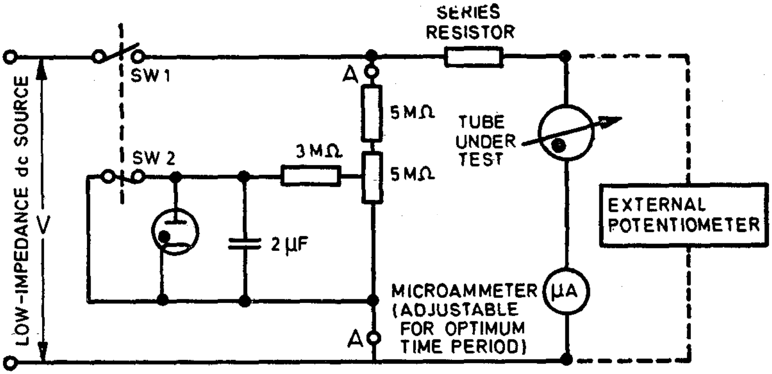
3.8.2 In the measurement of high 'Q' devices, especially for measurements near the bandwidth limits, substantially greater accuracy will be required.

4. METHODS OF MEASUREMENT

4.1 Primer (Keep-Alive or Ignitor) Measurements

4.1.1 *Ignition Time* — Unless otherwise stated, this measurement is performed with the tube in darkness. The tube is connected as shown in Fig. 1 and the stated dc voltage applied to the primer (ignitor) electrode or electrodes through a stated series resistor. The time required for the tube to ignite, as indicated by the microammeter reading, is measured. Each primer (ignitor) is measured individually when the tube has more than one primer (ignitor) electrode.

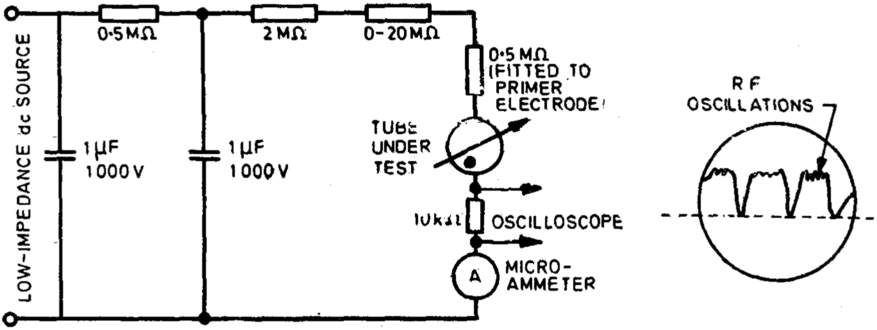
4.1.2 *Primer (Ignitor) Current* — The tube is connected as shown in Fig. 1. With the stated dc voltage(s) applied to the primer (ignitor) electrode(s) through the stated series resistor(s) the resultant current(s) is (are) measured.



NOTE — Counting circuit (between points A) may be omitted if an alternative time measurement is used.

FIG. 1 TYPICAL CIRCUIT FOR PRIMER CURRENT AND IGNITION MEASUREMENTS

4.1.3 *Oscillations* — When required, the presence of oscillations is detected by use of the circuit shown in Fig. 2. With the stated resistor connected in series with the tube, the applied dc voltage is varied and the minimum current required to prevent relaxation oscillations, as displayed on the oscilloscope trace, is determined. The high-frequency oscillations may be ignored (*see* Fig. 2A).



2A Typical Circuit for Primer Relaxation Measurements

2B Oscilloscope Trace During Measurement

NOTE — If an amplifier is used to give full screen deflection of the oscilloscope, the bandwidth of the system to 3 dB points should not be less than 50 Hz to 500 kHz, with an input impedance of 10 KΩ connected across a 10 KΩ monitor resistor.

FIG. 2 PRIMER RELAXATION MEASUREMENTS

4.1.4 *Primer (Ignitor) Drop* — The tube is connected to the primer (ignitor) supply through a variable series resistor, and the primer (ignitor) current adjusted to the stated value. The voltage drop between the primer (ignitor) electrode and the body of the tube is measured by one of the following methods (*see* Fig. 1).

Method 1 — By external potentiometer (connected as shown dotted) and adjusted so that no current flows through the potentiometer.

Method 2 — By connecting a voltmeter across points *A* and subtracting the voltage drop across the series resistor *R* from the voltage reading.

Method 3 — By connecting an electrostatic voltmeter across the tube.

Method 4 — By connecting a dc moving-coil voltmeter of high internal resistance in place of the potentiometer used in Method 1.

4.2 Low-Level RF Measurements

4.2.1 *Insertion Loss* — The loss is measured usually by the RF substitution method in a circuit as shown in Fig. 3, in which the device is inserted between a matched generator and a matched detector. To assure accuracy of ± 0·1 dB or better in the measurement of insertion loss, the vswr of the termination on the load side and generator side should not exceed 1·1 : 1 when the tube vswr is 1·17 or less. When higher values of the tube vswr are experienced, correspondingly tighter limits are required.

a) *Primed or total insertion loss*

The stated voltage or current is applied to the primer (ignitor) electrodes, and the value of insertion loss measured by readjustment of the calibrated attenuator. The tube may be replaced by a section of waveguide of equal physical length. This result is usually expressed in decibels.

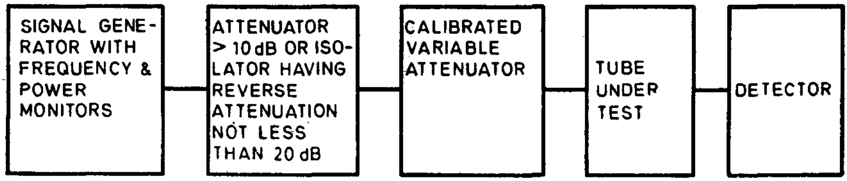

SIGNAL GENERATOR WITH FREQUENCY & POWER MONITORS
ATTENUATOR > 10 dB OR ISOLATOR HAVING REVERSE ATTENUATION NOT LESS THAN 20 dB
CALIBRATED VARIABLE ATTENUATOR
TUBE UNDER TEST
DETECTOR

FIG. 3 BLOCK DIAGRAM FOR TRANSMISSION SYSTEM MEASUREMENTS

b) *Cold or unprimed loss*

The value of insertion loss is measured as in **4.2.1** (a) but with no primer (ignitor) voltage applied. This result is usually expressed in decibels.

c) *Primer (ignitor) interaction loss*

The change of the insertion loss measured by the calibrated variable attenuator is noted during change from the primed condition to the unprimed condition.

This is the primer (ignitor) interaction loss.

Alternatively, the primer (ignitor) interaction loss may be obtained by substracting the value of the loss obtained in **4.2.1**(b) from the value obtained in **4.2.1**(a).

d) *Insertion loss of tunable integral cavity tube*

The frequency and power output of the signal generator are adjusted to stated values. The tube is then tuned to resonance. The insertion loss is measured as in **4.2.1**.

To ensure that any secondary peaks of transmitted power that may be present are not mistaken for the main peak, the displacement and relative amplitude of such secondary peaks are normally stated as illustrated in Fig. 4.

e) *Insertion loss of fixed-tuning tube*

The power output of the signal generator is adjusted to the stated value and the frequency adjusted to the resonance frequency of the tube. To ensure that any secondary peaks of transmitted power that may be present are not mistaken for the main peak, the displacement and relative amplitude of such secondary peaks are normally stated as illustrated in Fig. 4.

f) *Insertion loss of external-cavity tube (comparison method)*

The signal generator is adjusted to the reference frequency and the output power measured. The tube is then replaced by a suitable cavity calibrator (dummy tube) of known insertion loss and the change in output power is recorded. For a lossless dummy tube, the result of the measurement is the change in output, and is expressed in decibels.

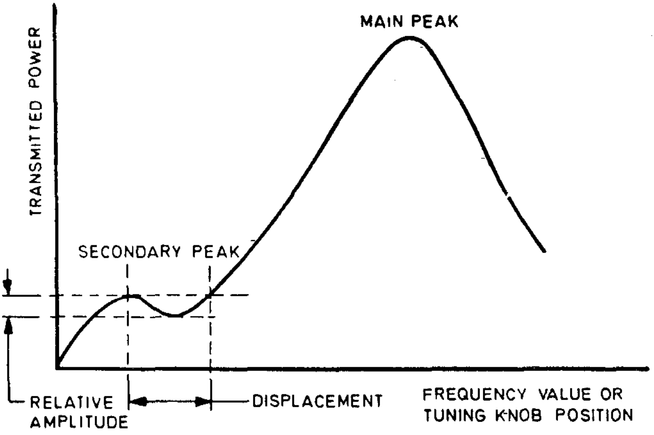


FIG. 4 REPRESENTATIVE TUNING CHARACTERISTIC INDICATING A SECONDARY PEAK

4.2.2 *Primer (Ignitor) Noise or Noise Figure Degradation* — The tube is connected to the input of a receiver having a stated noise factor. The increase of noise factor obtained on the application of the stated primer (ignitor) current through the tube is recorded. If the application of primer (ignitor) current causes the tube vswr value to change by more than 5 percent it is desirable to cancel this change by the use of a variable mismatch unit.

4.2.3 *Voltage Standing Wave Ratio (VSWR)*

a) *TR tubes*

The tube is inserted into a suitable low-level transmission circuit equivalent to that shown in Fig. 5, between a matched signal source and a matched load. The signal generator is tuned to the reference frequency. The vswr is then measured. This measurement is performed with the primer (ignitor) voltage applied to primer (ignitor) electrode(s).

b) *Pre-TR tubes and TR tubes for use in balanced circuit*

The tube is inserted into its duplexing mount and connected in a transmission circuit equivalent to that shown in Fig. 5. To ensure accuracy of measurement, the vswr in the line connected to any arm of the duplexing mount should not exceed 1·2 : 1. The signal generator is tuned to the reference frequency. The vswr is then measured.

NOTE — In special circumstances the transmitter arm of the duplexing mount is terminated by a variable short circuiting plunger to simulate a transmitting tube during its 'off' period. In this case, the vswr is measured with the plunger adjusted through all phases and the worst value recorded. The vswr under all stated conditions is measured with the tube position in the duplexing mount varied to include all positions for which the discharge region of the tube couples into the two channels of the duplexer.

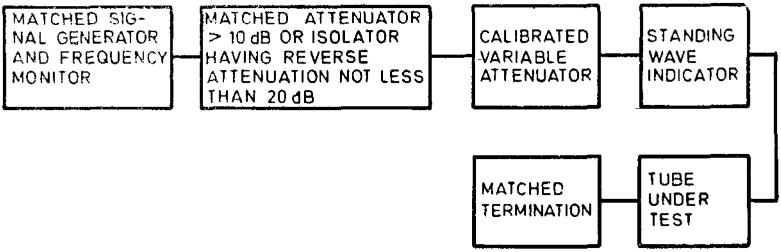

MATCHED SIGNAL GENERATOR AND FREQUENCY MONITOR
MATCHED ATTENUATOR > 10 dB OR ISOLATOR HAVING REVERSE ATTENUATION NOT LESS THAN 20 dB
CALIBRATED VARIABLE ATTENUATOR
STANDING WAVE INDICATOR
MATCHED TERMINATION
TUBE UNDER TEST

FIG. 5 BLOCK DIAGRAM FOR MEASUREMENTS IN TRANSMISSION-LINE CIRCUITS

4.2.4 *Tuning Range*

4.2.4.1 *Method A* — This measurement should be made in the circuit shown in Fig. 5. The resonance of the tube should cover the minimum frequency range required. The resonance of the tube is indicated by the minimum value of vswr (TR) or by the maximum value of vswr (ATR) (*see* **3.7**).

4.2.4.2 *Method B* — The measurement is made in the circuit shown in Fig. 3 (the calibrated variable attenuator may be omitted). Resonance of the tube is indicated by the maximum indication of the meter.

NOTE — This method is particularly suitable for the measurement of narrow-band tubes.

4.2.5 *Resonance of Fixed-Tuning Tube* — The tube is inserted between a matched signal generator and a matched detector. The signal generator frequency is then varied to obtain the resonance frequency of the tube.

4.2.6 *Centre Frequency* — The tube is inserted between a matched signal generator and a matched load in the circuit as shown in Fig. 5. The frequency is then varied over a stated band, and a number of vswr values corresponding to frequencies within that band are determined. From the resulting vswr/frequency characteristic curve, the centre frequency is computed as the geometric mean of any two frequencies at which the vswr values are equal and within a stated range.

4.2.7 *Transmitter-Receiver Isolation (Dual Gas-Switching Tubes)*

4.2.7.1 This test determines, how effectively the transmitter is decoupled from the receiver during the reception of a low-power signal at the antenna port.

4.2.7.2 *Procedure* — With the tube under test inserted in the circuit as shown in Fig. 6, the power in the receiver port, P_r, is measured. The matched termination at the transmitter port and the power meter at the receiver port are then interchanged, and the power at the transmitter port, P_t, is measured. This test may also be performed with two matched power meters, one at the transmitter port, and one at the receiver port, allowing P_t and P_r to be read at the same time.

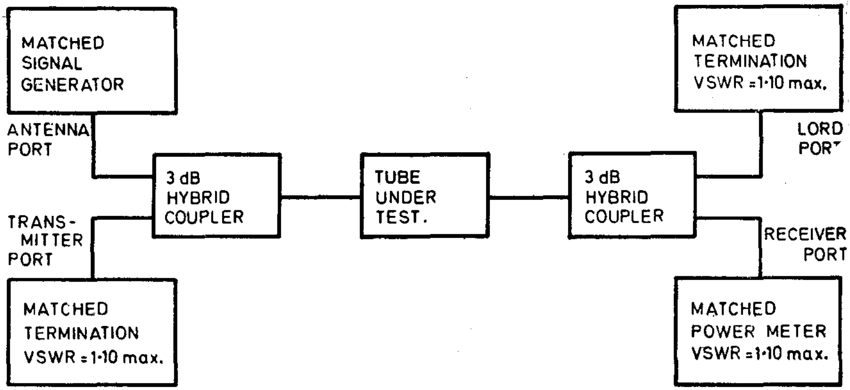


FIG. 6 EQUIPMENT LAYOUT FOR TRANSMITTER-RECEIVER ISOLATION MEASUREMENTS

4.2.7.3 The isolation is then calculated as

$$\text{Isolation} = 10 \log \frac{P_r}{P_t}$$

Alternatively, if P_r and P_t are measured in dB

$$\text{Isolation} = P_r\ (\text{dB}) - P_t\ (\text{dB})$$

4.2.7.4 *Precautions* — The 3 dB-hybrid couplers used shall have a maximum terminated vswr of 1·10 over the specified frequency range; split the power evenly to within 0·25 dB; and shall have a minimum isolation of 25 dB.

4.2.8 *Temperature Coefficient of Frequency (Gas-Switching Tubes)*

4.2.8.1 This method is to determine the shift in resonant frequency of a tube over a specified range of temperature.

4.2.8.2 *Method A (For tunable tubes)* — The tube shall be placed in a temperature-controlled chamber at room temperature and connected in a transmission circuit between a matched signal generator and detector. With the signal source set at the reference frequency, the tube shall be tuned to resonance as indicated by a pronounced peak of the output indicator. The temperature in the chamber shall then be reduced to 0°C and the tube body allowed to come to thermal equilibrium. The resonant frequency of the tube at 0°C shall be determined by returning the signal source for a peak of the output; the procedure shall then be repeated at +100°C. The frequency change of the tube over the temperature range shall be within the limits specified.

4.2.8.3 *Method B (fixed tuned tubes)* — The tube shall be mounted in the specified external cavity and placed in a circuit as specified in **4.2.8.2**. The signal source shall be tuned to the resonant frequency of the tube and cavity as indicated by a pronounced peak of the output indicator. The frequency shall be recorded and the procedure of **4.2.8.2** shall then be followed. The frequency change over the temperature range shall be within the limits specified.

4.2.9 *Normalized Equivalent Conductance and Susceptance (ATR Tubes)* — The tube is inserted into a transmission line circuit as shown in Fig. 5 with the matched termination replaced by a variable short-circuiting plunger. The operating conditions are set to stated values. Measurements of vswr are made over the required frequency band, with the variable short-circuiting plunger adjusted at each measurement frequency to produce a minimum value of vswr from the resultant vswr frequency characteristic curve, the normalized conductance (g) and susceptance (b) values may be derived as follows:

$$g = \frac{1}{r_0}$$

$$b = \pm\sqrt{\frac{g}{r} - g^2} = \pm\sqrt{\frac{1}{r_0}\left(\frac{1}{r} - \frac{1}{r_0}\right)}$$

where

r_0 = The maximum value of the vswr indicated on the vswr/frequency curve, and

r = vswr at any frequency.

The maximum value of the vswr frequency curve will occur at the resonance frequency of the tube.

These formulae apply to a series mount.

4.2.9.1 *Normalized equivalent conductance (alternative method of measurement)* — The normalized conductance may also be measured by one of the following methods in the circuit shown in Fig. 5.

a) *Method A* — The tube is inserted between a matched signal generator and a matched load. The vswr (r) is measured over a narrow band of frequencies around the resonance frequency, and a vswr/frequency curve obtained. The maximum value of vswr (r_0) occurs at the resonance frequency of the tube when the susceptance is zero. The normalized equivalent conductance is obtained from

$$g = \frac{1}{r_0 - 1}$$

b) *Method B* — The tube is inserted as in Method A with the load replaced by a matched power-reading detector. The normalized equivalent conductance is obtained by the measurement of the ratio of (1) incident power (P_1) upon the tube, to (2) the transmitted power (P_t) to the matched detector when the frequency of the signal generator is adjusted to the resonance frequency of the tube. The value of normalized equivalent conductance is

$$g = \frac{1}{2(k - 1)}$$

where $k = \sqrt{P_1/P_t}$.

The change in attenuator reading when the tube is replaced by a specified short-circuit can be used to obtain the ratio

$$\frac{P_1}{P_t}$$

c) *Method C (Comparison Method)* — The tube is inserted into its mount and inserted into the circuit shown in Fig. 7. During operation at the reference frequency, the short-circuiting plunger is adjusted for minimum reading on the matched power detector. This reading is recorded.

The tube is measured on a relative basis by comparison of (1) the observed reading from the matched detector, with (2) the calibration curve of the detector output obtained by the use of tubes that have previously been measured by Method A or Method B.

NOTE — During all measurements, by any of the three methods, the measurement frequency is the resonance frequency of the tube being measured, and it is essential that the power output from the signal generator remains constant during the period of the measurement.

4.2.9.2 *Normalized equivalent susceptance* — The tube is inserted into its mount between a matched generator and a matched load; as indicated in Fig. 5. The susceptance may be measured by one of the following methods:

a) *Method A* — The normalized equivalent susceptance is measured by comparing the position of the standing wave in front of the tube with the position obtained by using a reference tube having the same physical configuration and resonant at the reference frequency.

The susceptance is then computed by use of the following formula:

$$b = \frac{1 + 2g}{2} \tan \frac{4\pi \, \Delta l}{\lambda_g}$$

where

Δl = shift in position of the voltage standing wave from the sample tube to the reference tube,

λ_g = guide wavelength at reference frequency (in the same units as Δl).

For small values of Δl the expression may be written:

$$b = (1 + 2g) \frac{2\pi \, \Delta l}{\lambda_g}$$

Alternatively, the circuit may be equivalent to that shown in Fig. 7, and Δl obtained from adjustment of the short-circuiting plunger.

b) *Method B* — The tube is inserted into a transmission circuit between a matched generator and a matched load (*see* Fig. 7). This method requires the determination of the ratio of the power (P_1) incident on the tube to the power (P_t) transmitted through the tube to the load measured at the reference frequency. The normalized equivalent susceptance of the tube may then be computed by using the following formula:

$$b^2 = \frac{(1 + 2g)^2 - 4g^2 k^2}{4(k^2 - 1)}$$

where $k = \sqrt{P_1/P_t}$

The reflected power from the tube is comparable in magnitude to the incident power, and hence care should be exercised to select a directional coupler with adequate directivity for the measurement.

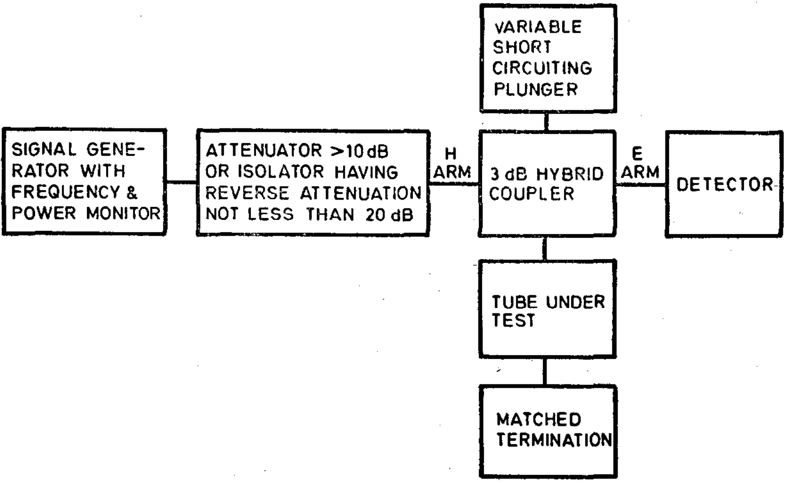

VARIABLE SHORT CIRCUITING PLUNGER
SIGNAL GENERATOR WITH FREQUENCY & POWER MONITOR
ATTENUATOR >10 dB OR ISOLATOR HAVING REVERSE ATTENUATION NOT LESS THAN 20 dB
H ARM
3 dB HYBRID COUPLER
E ARM
DETECTOR
TUBE UNDER TEST
MATCHED TERMINATION

FIG. 7 BLOCK DIAGRAM OF ALTERNATIVE CIRCUIT FOR MEASUREMENTS OF CONDUCTANCE AND SUSCEPTANCE

4.2.10 *Q Measurement*

4.2.10.1 *Loaded Q — TR Tubes* — The tube is inserted into a transmission-line circuit between a matched signal generator and a matched detector (the measuring circuit is that of Fig. 5 except that the termination is a matched detector). There should be sufficient attenuation between the signal generator and the tube is to prevent frequency or power changes in the signal generator caused by the tuning of the tube. The loaded Q is measured by one of the following two methods:

a) *Method A* — The tube is tuned to resonance (f_0) with the signal generator operating at the reference frequency. The power output is measured. The frequency of the signal generator is then tuned to points above and below resonance where the measured output power is reduced to half the peak value. The two frequencies, f_1 and f_2 at which half-power readings are obtained, are recorded. The value of the loaded Q is:

$$Q_L = \frac{f_0}{f_1 - f_2}$$

It is essential that the output power of the signal generator be constant with less than 1 percent variation in the frequency band f_1 to f_2. If this is not possible, the frequency/output power characteristic of the signal generator is determined and the necessary corrections applied.

b) *Method B* — Measurements are made of the input vswr when the tube being measured is tuned to resonance at the reference frequency. The frequency of the signal generator is varied over a narrow band centred about the reference frequency. A vswr/frequency characteristic curve is then drawn.

The value of loaded *Q* may then be obtained by the following methods:

(i) By using the value of vswr (r_0) obtained at the resonance frequency (f_0) and the value of vswr (r_1) obtained at two frequency points, one on either side of the resonance frequency, the loaded *Q* value is computed by means of the formula:

$$Q_L = \frac{f_0}{\Delta f} \frac{\sqrt{(r_0 r_1 - 1)(r_1 - r_0)}}{(1 + r_0)\sqrt{r_1}}$$

where

r_1 = vswr value at $\pm \frac{\Delta f}{2}$ from f_0 and is expressed as a value greater than unity.

As this expression is based on the approximation

$$\frac{f^2 - f_0^2}{f f_0} \approx \frac{2 \Delta f}{f_0}$$

the value of r_1 should be taken in the frequency range where the vswr/frequency curve is practically symmetrical. To ensure accuracy, it is preferable to have a value of r_1 greater than 1·5 r_0.

ii) By using the value of vswr (r_0) obtained at resonance and computing a value of vswr (r) by means of one of the following formulae:

For high-*Q* tubes (*Q* value greater than 50):

$$r = \frac{r_0 + 1 + (r_0^2 + 1)^{\frac{1}{2}}}{r_0 + 1 - (r_0^2 + 1)^{\frac{1}{2}}} \quad \text{or}$$

for low-*Q* tubes (*Q* value less than 50) and for values of $r_0 \simeq 1$:

$$r = \frac{A + B}{A - B}$$

where

$$A = [(r_0 + 1)^2 + 0{\cdot}1]^{\frac{1}{2}} \text{ and}$$

$$B = [(r_0 - 1)^2 - 0{\cdot}1]^{\frac{1}{2}}$$

The calculated value of vswr (r) is then applied to the vswr/frequency characteristic and a corresponding value of Δf, say Δf_1 is obtained. The loaded Q may then be computed from:

for high-Q tubes

$$Q_L = \frac{f_0}{\Delta f_1} \text{ or}$$

for low-Q tubes

$$Q_L = \frac{f_0}{\Delta f_1} \; \frac{0{\cdot}316}{(1 + r_0)}$$

4.2.10.2 *ATR tubes* — The loaded Q can be expressed in terms of rate of change of susceptance with frequency at resonance ($\Delta b / \Delta f$) as follows:

$$Q_L = \frac{f_0 \dfrac{\Delta b}{\Delta f}}{2(1 + g)}$$

Since f_0 is close to the reference frequency, the reference frequency may always be employed in place of f_0 in the above equation.

The quantity $\Delta b / \Delta f$ may be determined by the measurement of b at two frequencies near f_0, in an interval narrow enough so that a linear relation may be assumed between b and f.

If the conductance and susceptance of the tube have been determined, as in **4.2.9**, $\Delta b / \Delta f$ is computed from the vswr/frequency characteristic.

An alternative method for the determination of $\Delta b / \Delta f$ is the following:

The tube is inserted into a circuit similar to that of Fig. 5, between a matched generator and a matched load. The position of the standing-wave maximum nearest to the plane of symmetry of the tube is determined as a function of frequency in the vicinity of the resonance frequency.

The rate of change at resonance ($\Delta l / \Delta f$) is derived and the quantity $\Delta b / \Delta f$ calculated as follows:

$$\frac{\Delta b}{\Delta f} = \frac{2\pi}{\lambda_g} (1 + 2g) \frac{\Delta l}{\Delta f}$$

where

λ_g = guide wavelength at reference;

g = normalized conductance of the tube; and

$\frac{\Delta l}{\Delta f}$ = rate of change of position of the standing-wave maximum, before the tube, with respect to frequency.

Since it is not possible to take measurements at the plane of symmetry within the tube, measurements are made at a remote point and transformed to the correct position The correct values can be determined from the relation:

$$\frac{\Delta l}{\Delta f} = k \frac{m}{-4} \left(\frac{\Delta \lambda_g}{\Delta f} \right)$$

where

k = measured slope of the line obtained by plotting the observed position of a voltage minimum as a function of frequency; and

m = odd number of quarter wavelengths measured at resonance from the reference minimum to the plane of symmetry of the tube.

Since the formula involves the approximation

$$\tan 4\pi \frac{\Delta l}{\lambda} \approx 4\pi \frac{\Delta l}{\lambda}$$

the variation Δl should be sufficiently small with respect to λ for the approximation to hold.

Undesired mode resonances can be excited because of differences between the dimensions of the ATR tube with its mount and the dimensions of the waveguide. These undesired modes results in low values of vswr at the resonance frequencies.

4.2.11 *Electrical Length (Phase Shift)* — The electrical length is measured by one of the two following methods:

a) *Method A* — The tube is inserted into the circuit of Fig. 8 or into an equivalent circuit. The signal generator is tuned to a suitable frequency and the amplitude of the two signals incident upon the slotted line is adjusted for them to be equal. A minimum in the standing wave pattern is located. The tube is then replaced by a section of waveguide having the same mechanical length (l). The change in position Δl of the minimum in the standing-wave pattern is measured. The electrical length is $1 + 2\Delta l$.

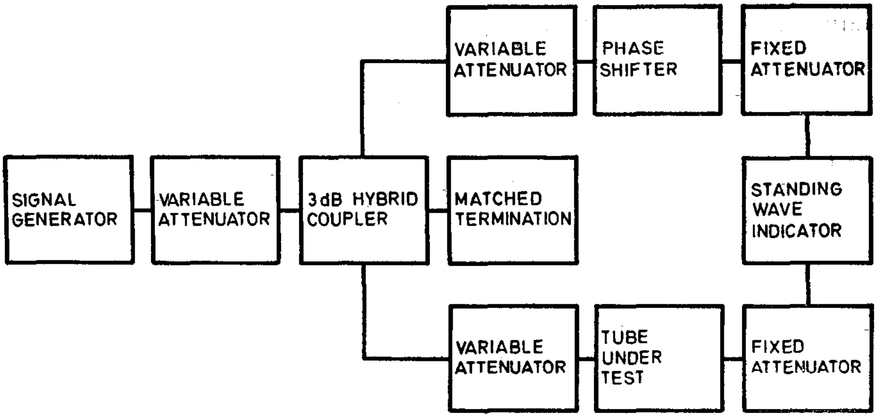


FIG. 8 BLOCK DIAGRAM OF CIRCUIT FOR MEASUREMENT OF ELECTRICAL LENGTH

b) *Method B* — The tube is inserted into the circuit of Fig. 7 with the matched load behind the tube replaced by a metallic short-circuit at the output flange of the tube. The signal generator is tuned to the reference frequency and the short-circuiting plunger adjusted to give minimum detector output. The tube is then replaced by a section of wave-guide having the same mechanical length (l) and short-circuited at its output. The resulting change in position ($\triangle l$) of the variable short-circuiting plunger to give minimum detector ouput is measured. The electrical length of the tube is $l + \triangle l$.

4.3 High-level RF Measurements

4.3.1 *Firing Time* (*ATR and Primerless Tubes*) — This measurement is made after the holding period and before any other high-level measurement. The measuring system contains a mount for the tube and is suitably terminated as shown in Fig. 9. The RF power is adjusted to the stated level with a short-circuit in the mount in place of the tube. The short-circuit is then removed and the tube inserted. The measured period of time required for the tube to fire after the application of RF power is the firing time.

4.3.2 *Arc Loss* — The tube is inserted into the circuit shown in Fig 9. The RF power is adjusted to the required level and the power transmitted (P_t) noted.

The tube is then replaced by a specified short-circuit and the transmitted power (P_s) again noted. The arc loss in decibels is then:

$$10 \log \frac{P_s}{P_t}$$

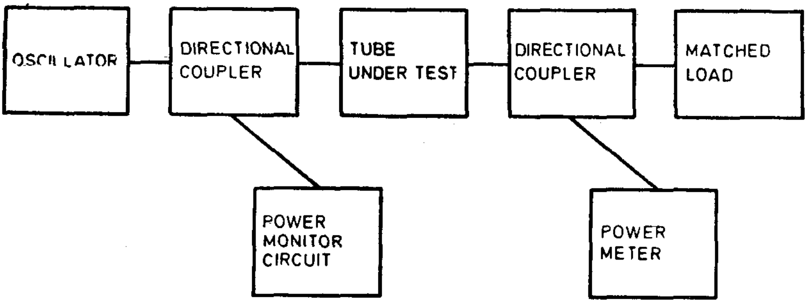


FIG. 9 BLOCK DIAGRAM OF CIRCUIT FOR MEASUREMENT OF ARC LOSS AND INCIDENT POWER

4.3.3 *High Level vswr* — The tube is inserted into the circuit shown in Fig. 10. The RF power in the main line is adjusted to the required level, and the vswr immediately before the tube is measured. Where the measurement is to be done on a dual tube, the 3 dB-hybrid coupler shall be suitably used so as to split the power evenly between the two sections.

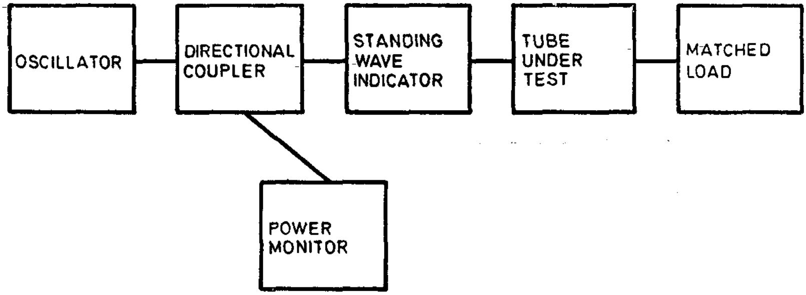


FIG. 10 BLOCK DIAGRAM OF CIRCUIT FOR MEASUREMENT OF VSWR AT HIGH POWER LEVELS

4.3.4 *Leakage Measurements*

4.3.4.1 *Total leakage power* — The tube is connected as shown in circuit of Fig. 11. The RF power in the main line is adjusted to the required level and the leakage power measured on the matched power detector. For the purpose of this measurement, the leakage pulse is deemed to be rectangular and to have the same pulse duration as the RF power pulse. The total leakage power may be computed from the formula:

$$\text{Total leakage power} = \frac{\text{Average leakage power (W)}}{\text{Pulse repetition frequency} \times \text{RF Pulse duration}}$$

The result is expressed in watts.

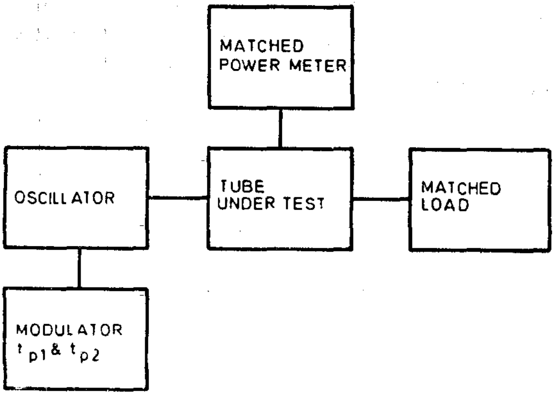


FIG. 11 BLOCK DIAGRAM FOR LEAKAGE POWER MEASUREMENTS

4.3.4.2 *Maximum low-power leakage* — The tube is connected in the circuit of Fig. 12. The operating conditions are adjusted as required. Commencing at a low level, the power is raised to a higher level. The maximum value of leakage power indicated is recorded.

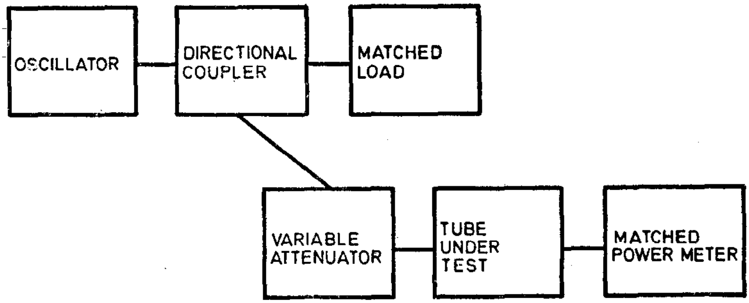


FIG. 12 BLOCK DIAGRAM FOR MAXIMUM LOW POWER LEAKAGE MEASUREMENTS

4.3.5 *Recovery Period*

4.3.5.1 *Method A — Attenuation Method*

a) *By use of a pulse probe signal* — The tube is connected as shown in Fig. 13. The tube is tuned to the reference frequency and the primer (ignitor) current adjusted. The low-power signal generator is tuned to the reference frequency and its output is introduced into the main line through a suitable coupling device. The power transmitted through the tube is amplified and the output applied to the vertical deflection plates of a suitable oscilloscope whose horizontal sweep is synchronized with the transmitter modulator.

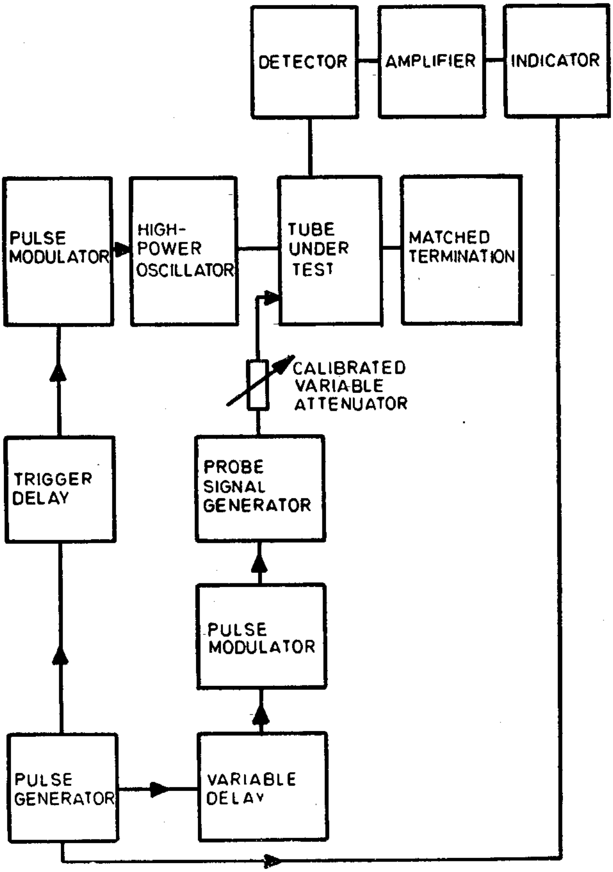


Fig. 13 Block Diagram of Circuit for Measurement of Recovery Time

As the low-level signal is varied in time with respect to the transmitted pulse, the variation of low-level signal amplitude indicated on the monitor is observed. Comparison of attenuation is made with respect to the amplitude of the low-level signal obtained when the time delay after the RF high-power pulse is such a large proportion of the pulse repetition period that the tube can be considered as completely recovered to the state which existed prior to the transmitter pulse.

Alternatively, by using the fixed delay in the transmitter modulator trigger circuit, the low-level signal can be made to appear before the transmitter pulse.

The recovery time is measured from the trailing edge of the transmitted pulse to the front edge of the low-level pulse. This measurement may be conveniently made by measuring the time delay from the front edge of the transmitter pulse and subtracting the value of the transmitter pulse duration. The measurement of time may be made by the use of a calibrated variable delay or by the superimposition of a signal of a suitable frequency on the time base of the monitor.

Precautions

Because the frequency response of the amplifier may modify the shape of the low-level pulse, the measurements concerning amplitude of pulse should be made at the centre of the low-level simulating pulse.

Care should be exercised to ensure that RF leakage power does not saturate the amplifier and thus introduce possible error into the measurement of recovery time because of the recovery period of the amplifier circuits. Care should be taken to avoid ringing in the amplifier circuits.

b) *Using cw Probe Signal*

Method (a) is followed, but with the substitution of cw signal for the low-level pulse modulated signal. With this modification, which is particularly useful for tubes having short recovery times, the recovery characteristic is displayed directly on the oscilloscope. In this case the recovery time is measured as the time delay between the tracking edge of the transmitter pulse and the — 3dB level of the cw reference signal.

Precautions

Adequate attenuation is necessary to prevent detector crystal burn-out. If a TR tube is used following the pre-TR tube, the two should be well matched. If the loading cannot be adjusted, resistive padding may be used between the tubes. Precautions should be taken to ensure that the TR tube recovery characteristic will not affect the measurement of the pre-TR tube recovery time.

4.3.6 *Attenuation Characteristic* (*Microwave Attenuators*) — The tube is included in a transmission system between a matched cw generator (or square-wave-modulated signal generator (and a calibrated attenuator followed by a matched detector. The output from the detector is amplified and passed through a calibrated attenuator to an indicator. The signal generator is tuned to the reference frequency, and with RF attenuator set to maximum, transmitted power is recorded.

The attenuator electrode current is then set to the required value, and the calibrated attenuator adjusted until the output indication returns to the original value.

The result of the measurement is the signal attenuation caused by the attenuator electrode current, which is equal to the change in attenuator setting. This is usually expressed in dB.

4.3.7 *Short-circuit Position*

4.3.7.1 *Method A* — The measuring equipment is connected as shown in Fig. 14. By the use of a low-power source, the position of the adjustable short-circuiting plunger should be adjusted to give minimum reflected power when the tube is replaced by a stated short-circuit. The tube is then inserted into the arm of the magic tee. The RF output power from the source is adjusted to the stated value. The calibrated variable short-circuiting plunger is then adjusted to give minimum reflected power in the line as indicated by a minimum in the power output detector.

The tube is then replaced by the stated short-circuit and the short-circuiting plunger re-adjusted for minimum reflected power. The difference in the short-circuiting plunger-settings corresponds to the distance between the reference plane of the stated short-circuit and the effective short-circuit produced by the fired tube.

4.3.7.2 *Method B* — With the equipment shown in Fig. 15, the RF power in the main line is adjusted for the stated conditions, and the positions of the voltage standing-wave minimum in front of the stated short-circuit are determined. The stated short-circuit is then replaced by the tube terminated by a matched load, and the shift in the position of the voltage standing-wave minimum is measured.

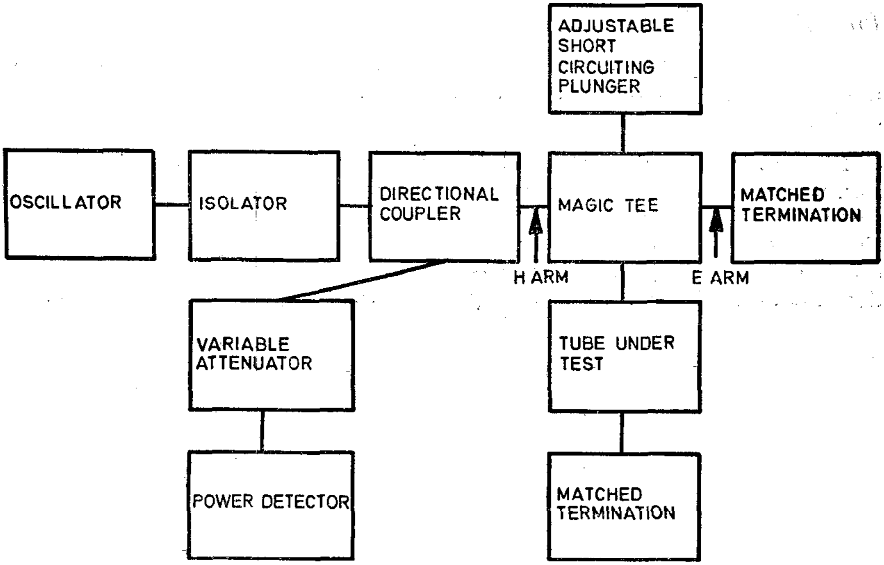


FIG. 14 BLOCK DIAGRAM OF CIRCUIT FOR MEASUREMENT OF SHORT-CIRCUIT POSITION — METHOD A

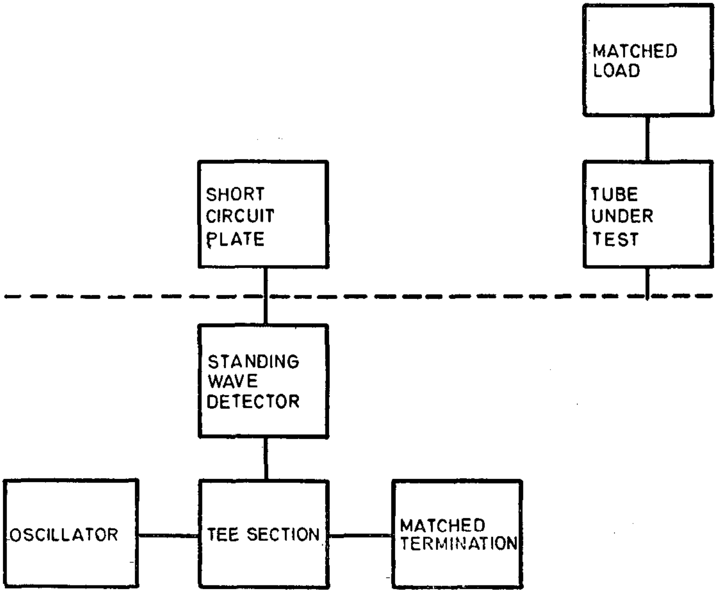


FIG. 15 BLOCK DIAGRAM OF CIRCUIT FOR MEASUREMENT OF SHORT-CIRCUIT POSITION — METHOD B

Precautions

Care must be taken to ensure that neither the position of the tube nor that of the stated short-circuit causes significant oscillator mismatch detuning.

4.3.8 *Firing Power* — The tube is connected in the circuit shown in Fig. 9 and operated under stated conditions. The RF power incident upon the tube is raised from a low level until the tube fires. The firing of the tube is indicated by a rapid decrease in the power recorded by the power detector in front of the load. The incident power that just causes the tube to fire is measured. This power is the firing power of the tube.

INDIAN STANDARDS ON ELECTRON TUBES

IS:

1885 (Part IV/Sec 1)-1973 Electrotechnical vocabulary : Part IV Electron tubes, Section 1 Common terms (*first revision*)
1885 (Part IV/Sec 2)-1973 Electrotechnical vocabulary : Part IV Electron tubes, Section 2 X-ray tubes (*first revision*)
1885 (Part IV/Sec 3)-1970 Electrotechnical vocabulary : Part IV Electron tubes, Section 3 Microwave tubes
1885 (Part IV/Sec 4)-1970 Electrotechnical vocabulary : Part IV Electron tubes, Section 4 Cathode-ray tubes
1885 (Part IV/Sec 5)-1972 Electrotechnical vocabulary : Part IV Electron tubes, Section 5 Pulse terms
1885 (Part IV/Sec 6)-1972 Electrotechnical vocabulary : Part IV Electron tubes, Section 6 Noise in microwave tubes
1885 (Part IV/Sec 7)-1973 Electrotechnical vocabulary : Part IV Electron tubes, Section 7 Camera tubes
1885 (Part IV/Sec 8)-1973 Electrotechnical vocabulary : Part IV Electron tubes, Section 8 Photosensitive devices
2032 (Part IX)-1969 Graphical symbols used in electrotechnology : Part IX Electron tubes (other than microwave tubes)
2032 (Part XIII)-1971 Graphical symbols used in electrotechnology : Part XIII Microwave tubes
2597 (Part I)-1964 Code of practice for the use of electron tubes : Part I Commercial receiving tubes
2597 (Part II)-1967 Code of practice for the use of electron tubes : Part II Special quality receiving tubes
2597 (Part III)-1969 Code of practice for the use of electron tubes : Part III Transmitting and industrial tubes
2597 (Part IV)-1970 Code of practice for the use of electron tubes : Part IV Cathode-ray tubes
2597 (Part V)-1971 Code of practice for the use of electron tubes : Part V Rectifiers and thyratrons
2684 (Part I)-1972 Dimensions of electron tubes : Part I Miniature '9-pin type' (*first revision*)
2684 (Part II)-1972 Dimensions of electron tubes : Part II Miniature '7-pin type' (*first revision*)
2684 (Part III)-1971 Dimensions of electron tubes : Part III Octal base type
2684 (Part IV)-1971 Dimensions of electron tubes : Part IV Magnoval base type
2684 (Part V)-1972 Dimensions of electron tubes : Part V Local base type
3154-1965 Specification for X-ray tubes, diagnostic type
4096-1973 Method of measurement of optical focal spot size of X-ray tubes (*first revision*)
4147-1967 Method of measurements on conventional receiving electron tubes
4579-1968 Method of measurements on television picture tubes
4697-1968 Method of measurements on Geiger Muller counter tubes
5323-1969 Letter symbols and abbreviations for electron tubes
5627-1970 Methods of measurements on cathode-ray display tubes
5840 (Part I)-1970 Dimensions of cathode-ray tubes : Part I Tube outlines
5840 (Part II)-1970 Dimensions of cathode-ray tubes : Part II Base type
5840 (Part III)-1970 Dimensions of cathode-ray tubes : Part III EHT terminals
6134 (Part I)-1978 Methods of measurements on microwave tubes : Part I Common to all microwave tubes
6134 (Part II)-1973 Methods of measurement on microwave tubes : Part II Oscillator tubes

IS:	
6134 (Part III)-1973	Methods of measurement on microwave tubes : Part III Amplifier tubes
6134 (Part IV)-1977	Methods of measurement on microwave tubes : Part IV Magnetrons
6134 (Part V)-1980	Methods of measurement on microwave tubes : Part V Parasitic noise
6134 (Part VI)-1981	Methods of measurement of electrical characteristics of microwave tubes : Part VI Low-power oscillator klystrons
6134 (Part VII)-1981	Methods of measurement of electrical characteristics of microwave tubes : Part VII High-power klystrons
6134 (Part VIII)-1981	Methods of measurement of electrical characteristics of microwave tubes : Part VIII Gas-filled microwave switching devices
6134 (Part IX)-1981	Methods of measurement of electrical characteristics of microwave tubes : Part IX Backward-wave oscillator tube — 'O' type
6134 (Part X)-1981	Methods of measurement of electrical characteristics of microwave tubes : Part X Crossed-field amplifier tubes
6136-1971	Basic requirements for cathode-ray tubes
6214-1971	Phosphors for cathode-ray tubes
6567-1972	Radiation protection for an X-ray tube in a protective tube — housing operating between 10 and 400 kV
6568-1972	Implosion protection for TV picture tubes
6576-1972	Methods of measurements on gas-filled cold cathode indicator tubes
6577-1972	Methods of measurements on gas-filled cold cathode voltage stabilizing and voltage reference tubes
6757-1972	Dimensions for high tension cable terminations for X-ray tubes
6758-1972	Dimensions for high tension receptacles for X-ray tubes
7012-1973	Specification for X-ray tube shield
7144-1973	Methods of measurements on camera tubes
7146 (Part I)-1973	Methods of measurements on photosensitive devices : Part I Basic considerations
7146 (Part II)-1974	Methods of measurements on photosensitive devices : Part II Photo-tubes
7146 (Part III)-1974	Methods of measurements on photosensitive devices : Part III Photoconductive cells for use in the visible spectrum
7146 (Part IV)-1974	Methods of measurements on photosensitive devices : Part IV Photomultipliers
8319 (Part I)-1977	Dimensions of indicator tubes : Part I Tube, Type 1
8319 (Part II)-1977	Dimensions of indicator tubes : Part II Tube, Type 2
8319 (Part III)-1973	Dimensions of indicator tubes : Part III Tube, Type 3
8319 (Part IV)-1979	Dimensions of indicator tubes : Part IV Tube, Type 4
8441-1977	Methods of measurements on incidental X-radiation from electron tubes
9383 (Part I)-1979	Dimensions of sign indicator tubes : Part I Tube, Type 1
9383 (Part II)-1979	Dimensions of sign indicator tubes : Part II Tube, Type 2
9492-1980	Methods of measurement of RF/microwave leakage from integral circuit electron tubes